Seminar I: Tidal dwarf galaxies

General instructions

This document provides preparation instructions for the first of the two seminars forming part of the examination for the course *Physics of Galaxies* in 2015. The topic of this seminar is *Tidal dwarf galaxies*. While the existence of these objects has been know for quite some time, their properties remain puzzling and potentially at odds with our current picture of how dark matter should behave on subgalactic scales. The point of this exercise is to:

- Practice reading technical research papers (as opposed to popular articles, review papers or textbooks). As a professional astronomer most of the stuff you will read is likely to be of this variety.
- Practice critical thinking (for this purpose, speculative and controversial seminar topics have deliberately been chosen).
- Practice creativity. The answers you need may not be in the suggested literature – or in *any* publication for that matter. You may simply have to come up with a solution on your own.
- Practice information retrieval (learning not to waste time reading off-topic papers is an invaluable skill).
- Practice analyzing observational data
- Practice presenting material in front of an audience.

In preparing for the seminar, you should try to:

- Develop some insight into the field of tidal dwarf galaxies by studying the relevant literature. In doing so, the seminar questions listed may serve as guidance as to what you should focus on.
- Prepare to explain and discuss various concepts and recent results relevant to this field in front of the class. The use of computer, whiteboard or projector is highly encouraged.
- Analyze the enclosed tidal dwarf galaxy data set and prepare to present your findings to the class (using e.g. computer screen, whiteboard, projector or printouts).

You are perfectly welcome to collaborate with your classmates when preparing for the seminar, but once there – everyone is on their own. This means that you are not supposed to rely on the calculation, notes, printouts etc. of others.

Suggested reading

A couple of good places to start are:

- Duc, P.-A., 2011, in Dwarf Galaxies: Keys to Galaxy Formation and Evolution, Astrophysics and Space Science Proceedings, ISBN 978-3-642-22017-3. Springer-Verlag Berlin Heidelberg, 2012, p. 305 (arXiv:1101.4834)
- Bournaud et al. 2007, Science 316, 1166 (arXiv:0705.1356[1])

Please note that these papers represent the *minimum* reading required for the seminar. It is highly recommended that you study other articles as well. When looking for relevant papers, you may find the following keywords useful:

- Tidal dwarf galaxies
- Missing baryons
- MOND
- Dark matter disk

The recommended article databases are:

- http://adsabs.harvard.edu/abstract_service.html (to get published versions of papers)
- http://arxiv.org (preprints, some of which are too strange to ever get published)

Seminar questions

Here are a few examples (i.e. not a complete list) of questions that may come up during the seminar:

- What is a tidal dwarf galaxy?
- How common are they?
- What are their typical masses?
- Why are tidal dwarf galaxies considered a potential challenge for the cold dark matter model?

A tidal dwarf galaxy case study

A team of astronomers claim to have found a faint, recently formed dwarf galaxy in the HI tidal arm of an advanced galaxy merger (Fig. 1). By combining an Hα rotation curve with optical (B-band) photometry, HI and H_2 data, they argue that this object has $M/L_B \approx 125$ and is likely to be the most dark matter-dominated tidal dwarf galaxy (TDG) discovered so far. Following their announcement, a number of follow-up observations are carried out at various telescopes around the globe. Through one of your many collaborations, you happen to come across some of these new data (see Table 1). This includes the Hα emission-line equivalent width, the Hα/Hβ emission-line ratio and the K band flux of this galaxy. It is now up to you to analyze this information in order to extract as much as possible about the nature of the TDG.

The following questions may provide some guidance:

- Do the new data support the previous interpretation?
- Is the TDG as dark matter-dominated as previously claimed?

[1] In this case, it's better to get the paper from arXiv, since this version contains some additional appendices

- Are there alternative explanations for the properties of this object?
- What future observations or investigations (if any) would you propose to get additional clues about the nature of this object?

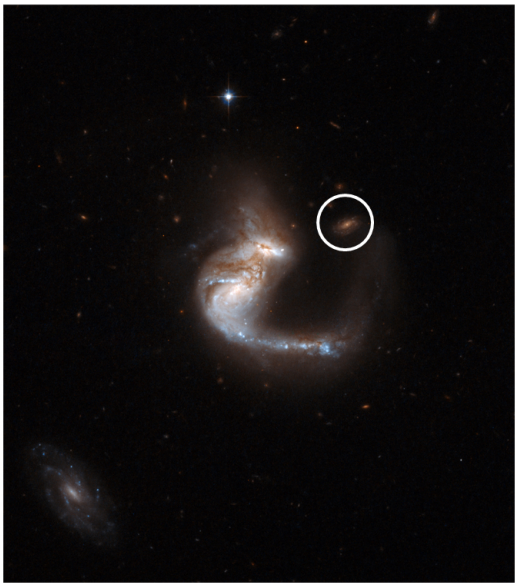

Figure 1: An optical image of a galaxy merger with a faint tidal dwarf galaxy candidate (marked by circle).

Erik Zackrisson, April 2015

Table 1: A compilation of the data available on the system depicted in Fig. 1

Original data:		
	$z_{\rm TDG}$:	0.0312±0.0015
	$m_{\rm B,TDG}$:	21.3 ± 0.1
	$M_{\rm HI,TDG}$ ($M_\odot$):	$1(\pm 0.1) \times 10^9$
	$M_{\rm H_2,TDG}$ ($M_\odot$):	$3(\pm 0.5) \times 10^8$
	$z_{\rm TDG\ host}$:	0.0336±0.0015
	$v(r = 1.1$ arcsec$)^1$ (km s^{-1}):	90 ± 10
	$v(r = 2.2$ arcsec$)^1$ (km s^{-1}):	160 ± 10
	$v(r = 3.3$ arcsec$)^1$ (km s^{-1}):	190 ± 10
New data:		
	EW(Hα) (Å):	400
	Hα/Hβ:	7.9
	$m_{\rm K,TDG}$:	15.6 ± 0.2

1) Corrected for inclination